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# RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

## DITCHING INVESTIGATION OF A 1/12-SCALE MODEL OF THE DOUGLAS F4D-1 AIRPLANE

TED NO. NACA DE 384

By John O. Windham

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON



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# DITCHING INVESTIGATION OF A 1/12-SCALE MODEL OF THE DOUGLAS F4D-1 AIRPLANE

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## SUMMARY

A ditching investigation was made of a 1/12-scale dynamically similar model of the Douglas F4D-1 airplane to study its behavior when ditched. The model was landed in calm water at the Langley tank no. 2 monorail. Various landing attitudes, speeds, and configurations were investigated.

The behavior of the model was determined from visual observations, acceleration records, and motion-picture records of the ditchings. Data are presented in tables, sequence photographs, time-history acceleration curves, and attitude curves.

From the results of the investigation, it was concluded that the airplane should be ditched at the lowest speed and highest attitude consistent with adequate control (near $22^{\circ}$) with landing gear retracted. In a calm-water ditching under these conditions the airplane will probably nose in slightly, then make a fairly smooth run. The fuselage bottom will sustain appreciable damage so that rapid flooding and short flotation time are likely. Maximum longitudinal deceleration will be about 4g and maximum normal acceleration will be about 6g in a landing run of about 420 feet. In a calm-water ditching under similar conditions with the landing gear extended, the airplane will probably dive. Maximum longitudinal decelerations will be about $5\frac{1}{2}$g and maximum normal accelerations will be about $3\frac{1}{2}$g in a landing run of about 170 feet.

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## INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, an investigation of a dynamic model of the Douglas F4D-1 airplane was made to determine the best way to land the airplane on the water and its probable ditching behavior. This airplane is of interest because of its unusual configuration. It is a flying-wing-type fighter with a delta-shaped wing and wing-root jet inlets. The ditchings of the model were made in calm water at the Langley tank no. 2 monorail.

## APPARATUS AND PROCEDURE

### Description of the Model

A three-view drawing of the Douglas F4D-1 airplane is given in figure 1. The 1/12-scale dynamically similar model of the airplane, shown in figure 2, was furnished by the Bureau of Aeronautics. The model was constructed principally of balsa wood with spruce or mahogany at areas of concentrated stress. Internal ballast was used to obtain scale weight and moments of inertia. The model had a wing span of 2.79 feet and an overall length of 3.78 feet. The elevons and trimmers were installed so that they could be held rigidly in various positions.

The probability of fuselage bottom damage and the hydrodynamic effect if damage occurred was investigated by replacing the original fuselage bottom with a framework of rigid bulkheads covered with aluminum foil. Undamaged model tests indicated that the rear portion of the fuselage bottom would absorb the initial impact and sustain the greatest damage. Therefore, only the rear portion of the bottom was replaced by the aluminum-covered frame (fig. 3). The aluminum covering resulted in a bottom about three times as strong on a scale basis as the 4-lb/sq in. bottom estimated for the airplane by the manufacturer. Since the aluminum covering always failed in the model test, indications are that the bottom of the full-scale airplane will also fail.

Model behavior in a wheels-down ditching was investigated by attaching the landing gear at scale strength. The landing gear was fastened to the model by a calibrated thread (see figs. 4 and 5) which would fail at approximately 17,000 pounds full scale for the nose gear and 20,000 pounds full scale per wheel for the main gear. (These values were estimated by the manufacturer.)

### Test Methods and Equipment

The model was attached to the launching carriage on the Langley tank no. 2 monorail (see ref. 1) at the desired landing attitude with the control surfaces set to hold this attitude in flight. The model was then catapulted into the air and the preset control surfaces kept the model at approximately the desired attitude during the glide from release to landing.

The results of the investigation were obtained from visual observations, motion-picture records, and time-history acceleration records. The accelerations were measured with a two-component accelerometer, placed in the pilot's compartment. Both normal and longitudinal components of acceleration measured with respect to the axis of the airplane were recorded. The natural frequency of the accelerometer was 73 cycles per second and it was damped to about 65 percent of critical damping. The accuracy with which the instrument could be read was estimated to be about ±1/4g.

## Test Conditions

All values given refer to the full-scale airplane.

Gross weight.- The design gross weight of 15,000 pounds was used in the investigation.

Moments of inertia.- The moments of inertia used in the investigation were as follows:

| | |
|---|---|
| $I_X$ (roll), slug-ft$^2$ . . . . . . . . . . . . . . . . . . . . . . . | 11,000 |
| $I_Y$ (pitch), slug-ft$^2$ . . . . . . . . . . . . . . . . . . . . . . . | 32,000 |
| $I_Z$ (yaw), slug-ft$^2$ . . . . . . . . . . . . . . . . . . . . . . . | 41,000 |

Location of the center of gravity.- The center of gravity was located on the thrust line at 24 percent mean aerodynamic chord.

Landing attitude.- Ditchings were made at three attitudes: 14° (near maximum tail down, static), 18° (intermediate), and 22° (near lift-curve stall). The attitude was measured between the fuselage reference line and the smooth water surface.

Landing speed.- The landing speeds used in the investigation were computed from power-off lift curves furnished by the manufacturer and are listed in table I.

Fuselage conditions.- The model was tested in the following conditions:

(a) No damage simulated

(b) Bottom framework of rigid bulkheads covered with aluminum foil

[redacted]

Landing gear.- The majority of the tests were made with the landing gear retracted. However, some tests with no fuselage damage simulated were made with the landing gear extended and attached at scale strength. Unless otherwise specified, the tests were made with the landing gear retracted.

## RESULTS AND DISCUSSION

A summary of the results of the investigation is presented in table I. The notations used in the table are defined as follows:

d dived - the model decelerated rapidly in a nose-down attitude and the nose submerged into the water

f flipped over - the model rotated about the transverse axis and stopped in an inverted position

h ran smoothly - the model made no apparent oscillation about any axis and gradually settled into the water as the forward speed decreased

m trimmed down - the model made a negative rotation about the lateral axis after contact with the water

n nosed in slightly - the model decelerated rapidly in a nose-down attitude and the nose partially submerged

s skipped - the model cleared or rebounded from the water

u trimmed up - the model made a positive rotation about the lateral axis after contact with the water

Sequence photographs of model ditchings are shown in figure 6. Figure 7 presents time histories of attitude, longitudinal deceleration, and normal acceleration for landings in the various damage conditions. Figure 8 shows typical damage to the aluminum-covered frame.

### Effects of Damage

The Douglas F4D-1 airplane lands at a very high attitude, and consequently the aft fuselage and trailing edge of the wing made first contact with the water (fig. 6). At the 22° landing attitude, the undamaged model with landing gear retracted trimmed down immediately after contact and then trimmed up and ran smoothly. At the 18° and 14° attitudes, the model trimmed down at contact and then trimmed up, skipped once or twice, and then ran smoothly. The lengths of landing runs for the undamaged model varied from 600 to 770 feet. Maximum longitudinal decelerations of 1g to 2g and maximum normal accelerations of $3\frac{1}{2}$ g to to $6\frac{1}{2}$ g were recorded for the three attitudes (table I and figs. 6(a) and 7(a)). The delta-shaped wing, with the control surfaces (elevons and trimmers) necessitated by this configuration, had no detrimental effect on behavior. The wing-root jet inlets had little effect on behavior of the undamaged model since they did not enter the water until the low-speed part of the landing runs.

When the aft portion of the fuselage bottom was replaced with rigid frames covered with aluminum foil, appreciable damage resulted (fig. 8). The model nosed in or dived, the accelerations were higher, and the runs were shorter than for the undamaged condition. Maximum longitudinal decelerations of about 4g to 8g and maximum normal accelerations of 4g to 6g were encountered in landing runs of about 340 to 420 feet (table I and figs. 6(b) and 7(b)). The damage permitted rapid flooding which made a short flotation time probable for the airplane. When fuselage damage occurred, the wing-root jet inlets entered the water during the high-speed part of the run and added to the drag of the model especially at the higher landing speeds.

## Effects of Landing Gear

In landing runs with the landing gear extended and attached at scale strength, the landing gear did not fail. The model either dived abruptly or flipped over. At the 22° attitude, the model dived; maximum longitudinal decelerations of about $5\frac{1}{2}$ g and maximum normal accelerations of about $3\frac{1}{2}$ g were encountered in a landing run of about 170 feet (table I and figs. 6(c) and 7(c)). In landings at the other attitudes, the model flipped over and the accelerations generally exceeded the 10g maximum longitudinal and the 6g maximum normal ranges of the accelerometer. Thus a ditching should always be made with landing gear retracted if possible.

## Effect of Landing Attitude and Speed

In general, the effect of landing attitude on behavior depended on the speeds associated with that attitude. The lower attitudes with the accompanying higher speeds resulted in motions more violent and undesirable than those of the higher attitudes and lower speeds. Consequently, a ditching should be made at the lowest speed and highest attitude (near 22°) consistent with adequate control.

## CONCLUSIONS

From the results of the investigation of a 1/12-scale dynamically similar model of the Douglas F4D-1 airplane, the following conclusions were reached:

1. The airplane should be ditched at the lowest speed and highest attitude (near $22^{\circ}$) consistent with adequate control.

2. The airplane with landing gear retracted will probably nose in slightly, then run smoothly in calm water. Maximum longitudinal decelerations of about 4g and maximum normal accelerations of about 6g are to be expected in a landing run of about 420 feet.

3. The fuselage bottom will sustain appreciable damage so that rapid flooding and short flotation time are likely.

4. The airplane with landing gear extended will probably dive abruptly. Maximum longitudinal decelerations of about $5\frac{1}{2}$ g and maximum normal accelerations of about $3\frac{1}{2}$ g are to be expected in a landing run of about 170 feet.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 19, 1956.

John O. Windham
John O. Windham
Aeronautical Research Scientist

Approved: John B. Parkinson
John B. Parkinson
Chief of Hydrodynamics Division

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## REFERENCE

1. Christopher, Kenneth W.: Effect of Shallow Water on the Hydrodynamic Characteristics of a Flat-Bottom Planing Surface. NACA TN 3642, 1956.

TABLE I

SUMMARY OF RESULTS OF DITCHING INVESTIGATION IN CALM WATER OF A

1/12-SCALE MODEL OF THE DOUGLAS F4D-1 AIRPLANE

[Gross weight, 15,000 lb; static normal accelerometer reading, 1g; all values are full-scale.]

| Landing attitude, deg | Elevon setting, deg | Trimmer setting, deg | Landing speed, knots | Motions (1) | Length of run, ft | Maximum longitudinal deceleration, g units (2) | Maximum normal acceleration, g units (2) |
|---|---|---|---|---|---|---|---|
| No damage | | | | | | | |
| 22 | 25 | 25 | 90 | m,u,h | 600 | 1 | $3\frac{1}{2}$ |
| 18 | 15 | 15 | 100 | m,u,s,h | 640 | 2 | 6 |
| 14 | 15 | 10 | 114 | m,u,s,h | 770 | 2 | $5\frac{1}{2}$ |
| Aluminum-covered frame installed | | | | | | | |
| 22 | 25 | 25 | 90 | n,h | 420 | 4 | 6 |
| 18 | 15 | 15 | 100 | n,h | 420 | 6 | 6 |
| 14 | 15 | 10 | 114 | d,h | 340 | 8 | 4 |
| Scale-strength landing gears installed | | | | | | | |
| 22 | 25 | 25 | 90 | d | 170 | $5\frac{1}{2}$ | $3\frac{1}{2}$ |
| 18 | 15 | 15 | 100 | d,f | 210 | 8 | -- |
| 14 | 15 | 10 | 114 | d,f | 200 | -- | -- |

[1]Motions of the model are denoted by the following symbols:

| | |
|---|---|
| d | dived |
| f | flipped over |
| h | ran smoothly |
| m | trimmed down |
| n | nosed in slightly |
| s | skipped |
| u | trimmed up |

[2]Accelerations of the model which exceeded maximum ranges of accelerometer and were omitted are denoted by dash (-).

 [redacted]

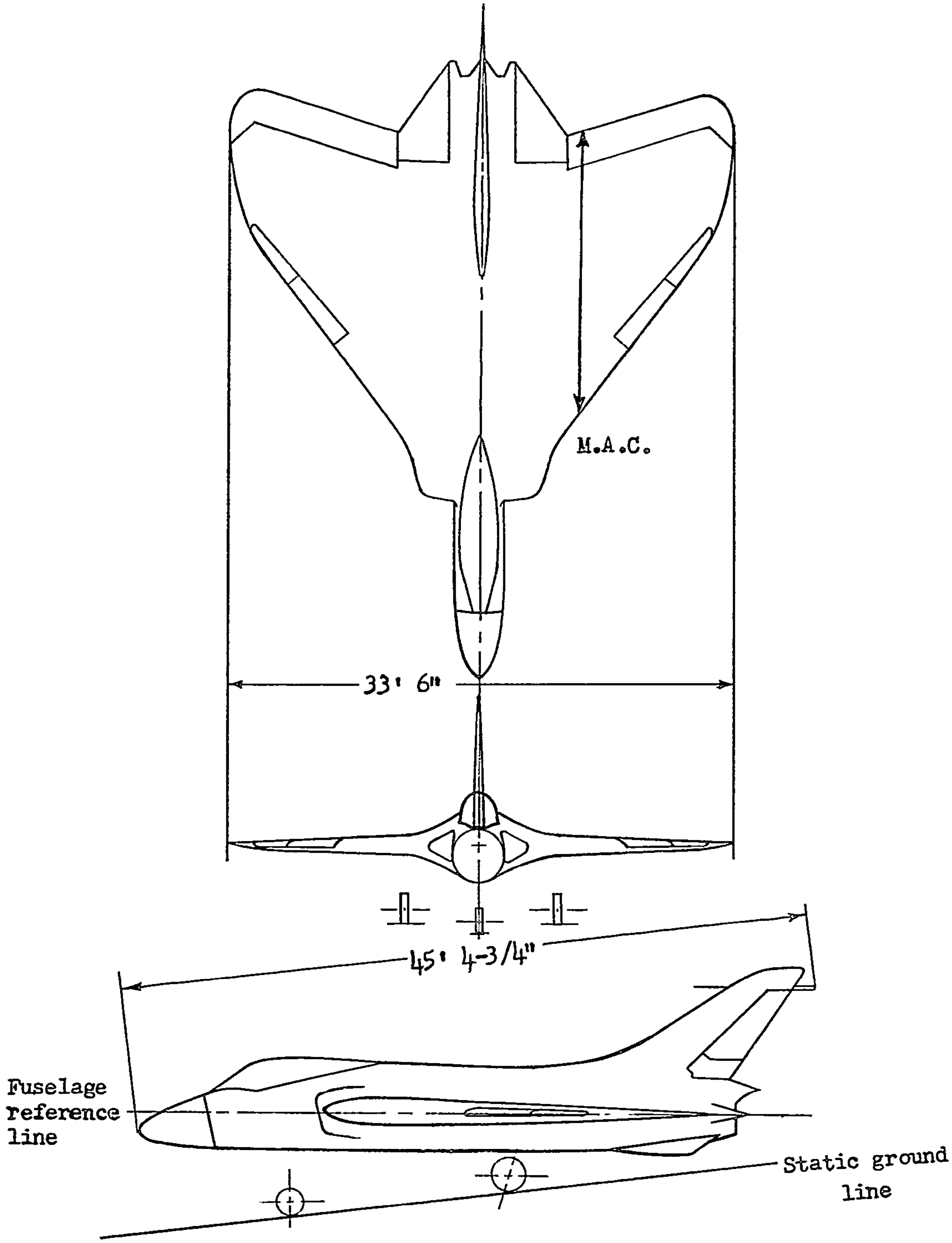
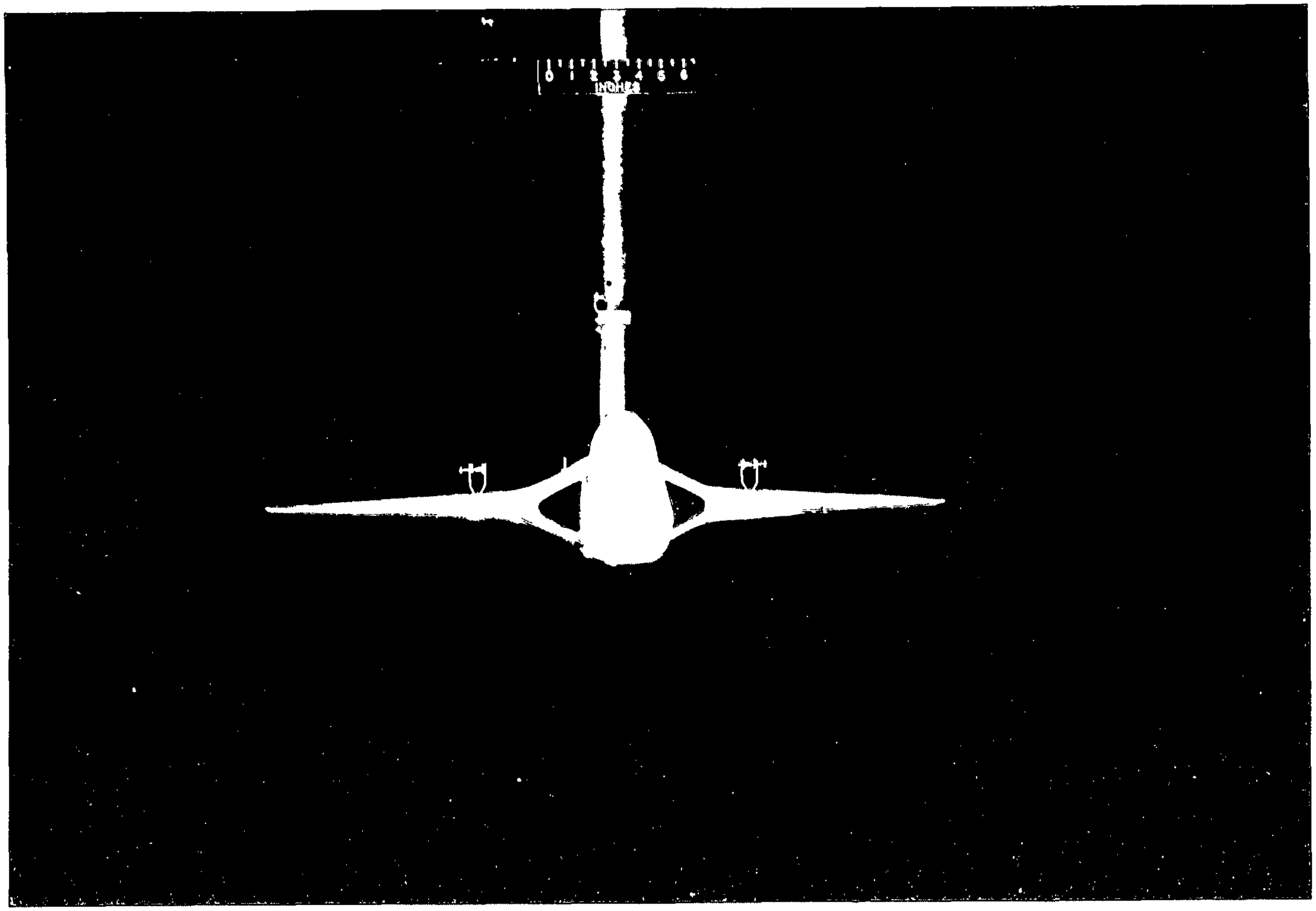



Figure 1.- Three-view drawing of Douglas F4D-1 airplane. (Dimensions are full size.)

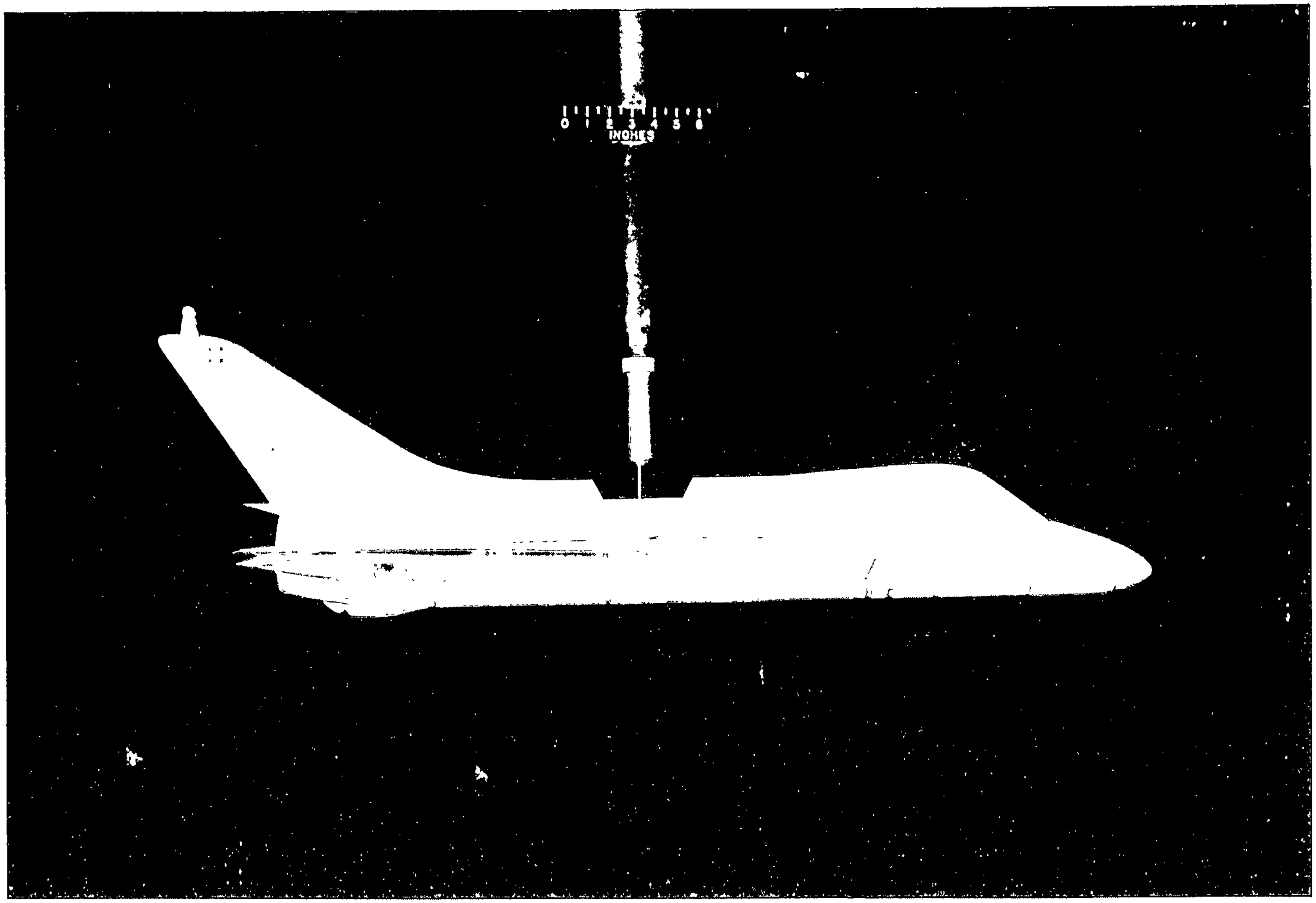
[redacted]



L-88631

(a) Front view.

Figure 2.- Model of the Douglas F4D-1 airplane.

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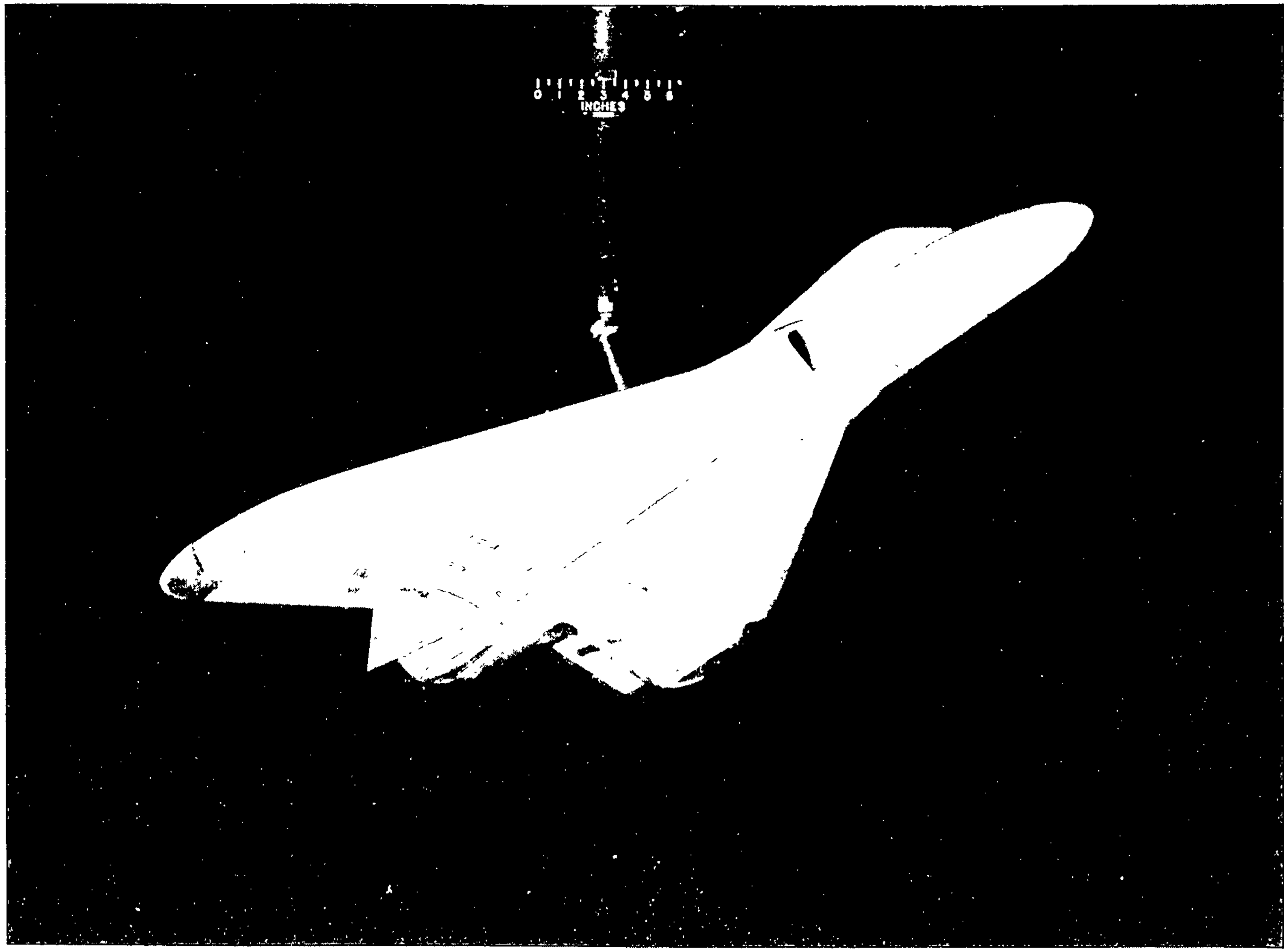
(b) Side view.

Figure 2.- Continued.

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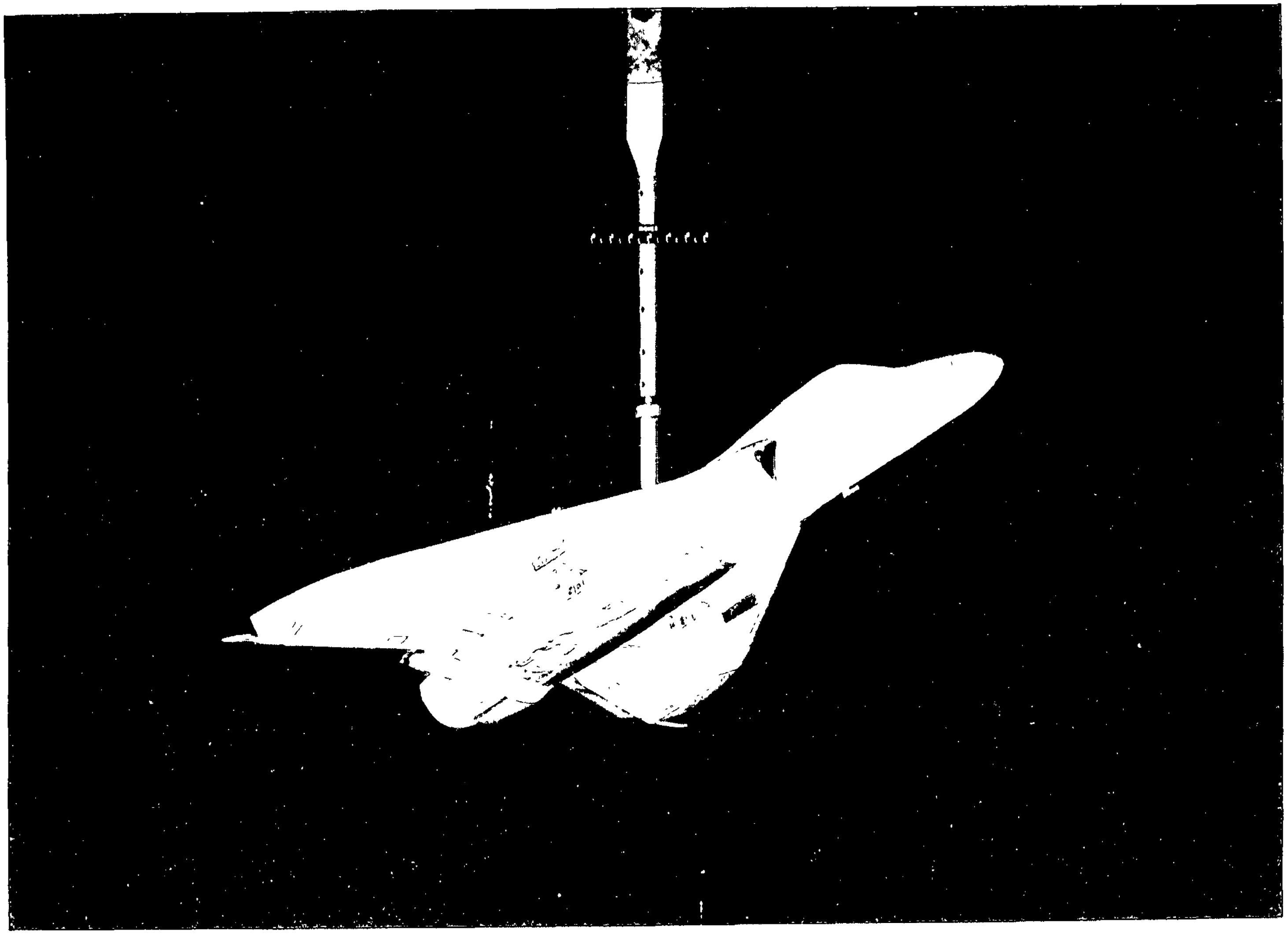
(c) Three-quarter bottom view.

Figure 2.- Concluded.



L-92736

Figure 3.- Model with aluminum-covered frame installed.

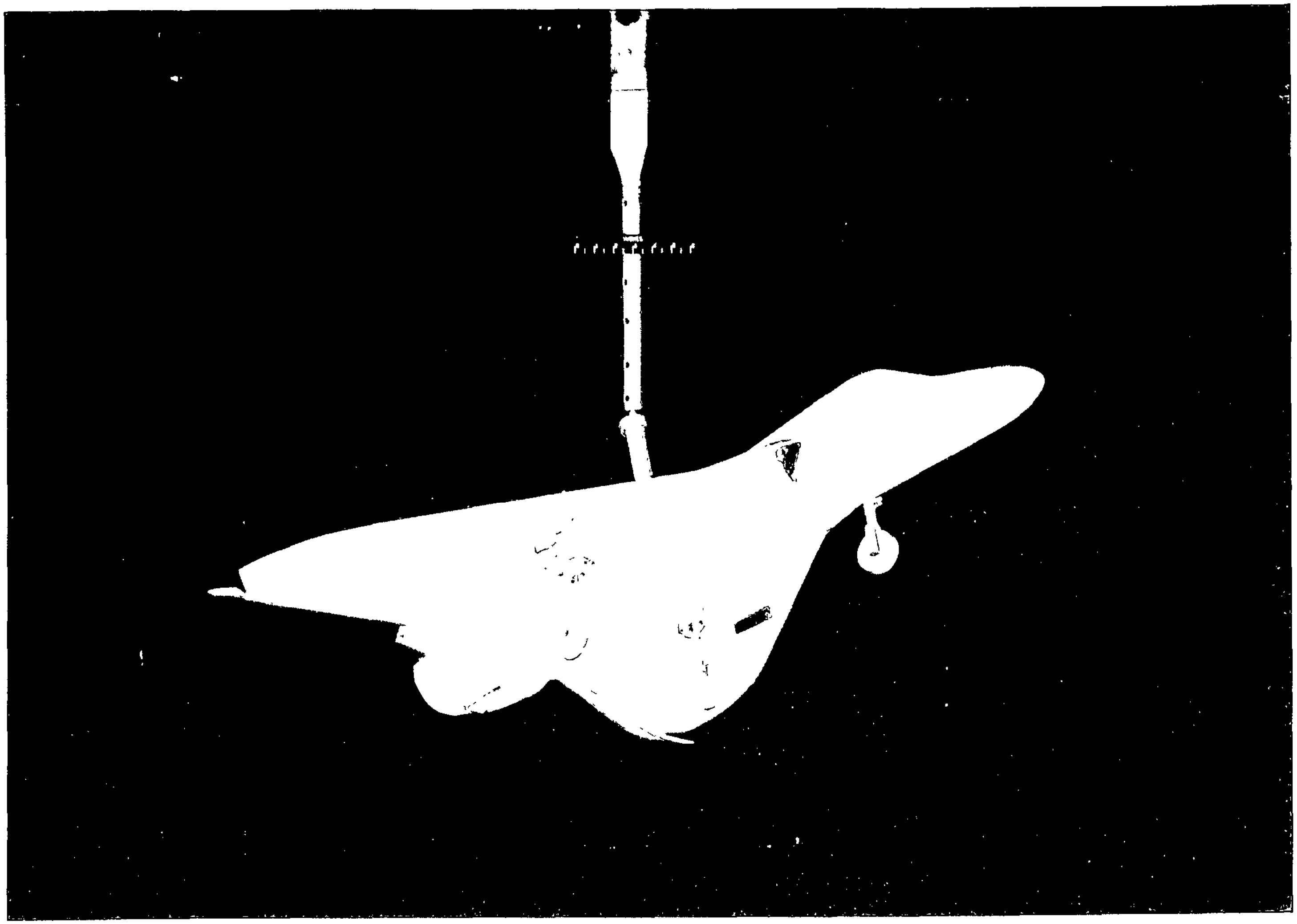


Figure 4.- Model with scale-strength landing gear installed. L-92737

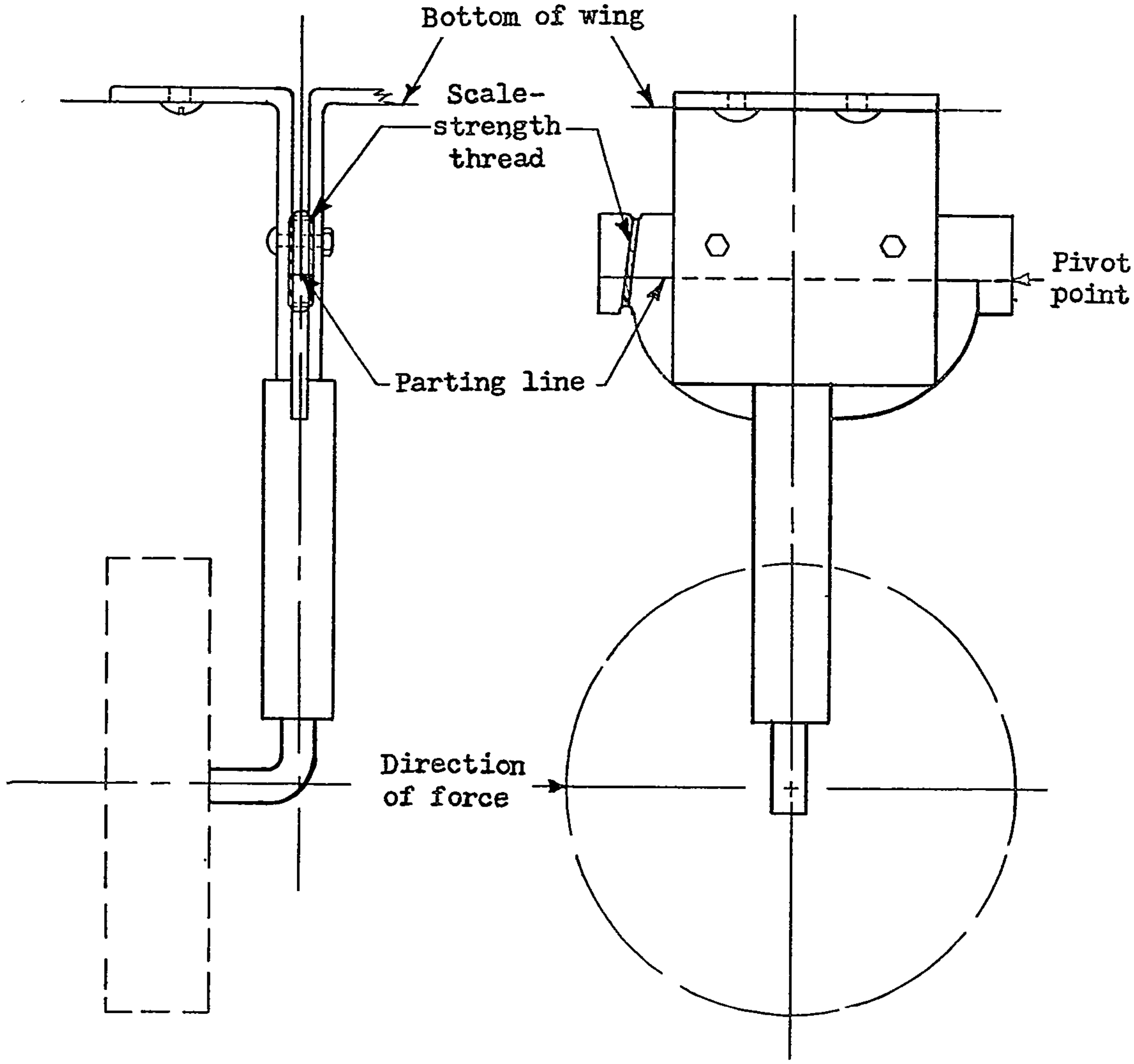
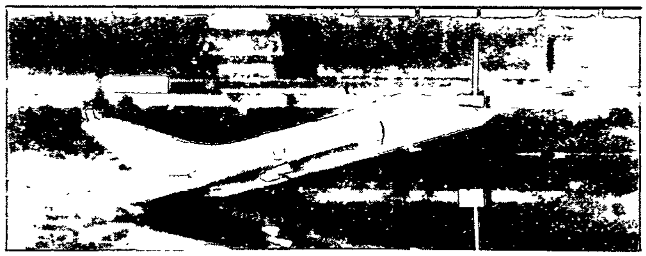



Figure 5.- Details of scale-strength attachment of landing gear.

Near contact

114 feet



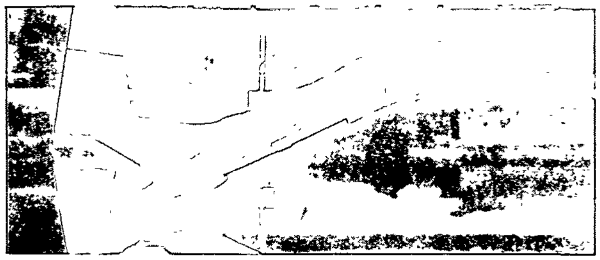
190 feet

444 feet

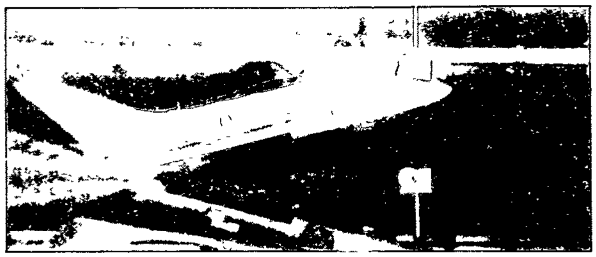
(a) No damage simulated. L-93545

Figure 6.- Sequence photographs of model ditching at the 22° landing attitude; landing speed, 90 knots. Distances after contact are indicated. (All values are full scale.)

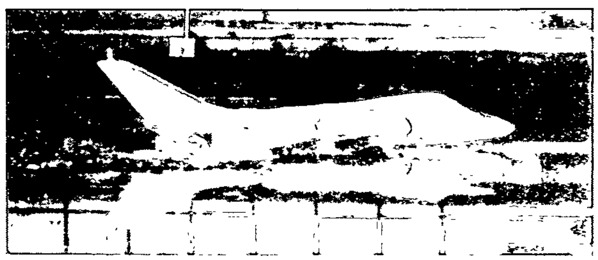
[redacted]



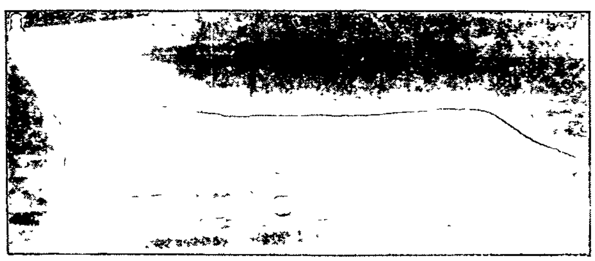
Near contact



60 feet



240 feet

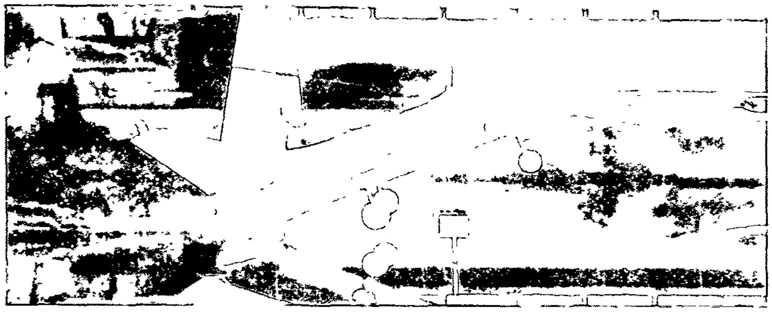


410 feet

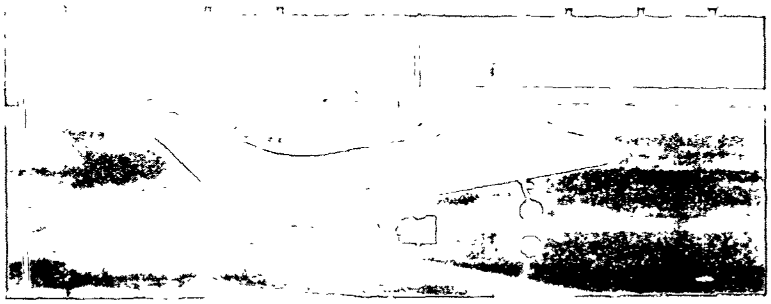
(b) Aluminum-covered frame installed. L-93546

Figure 6.- Continued.

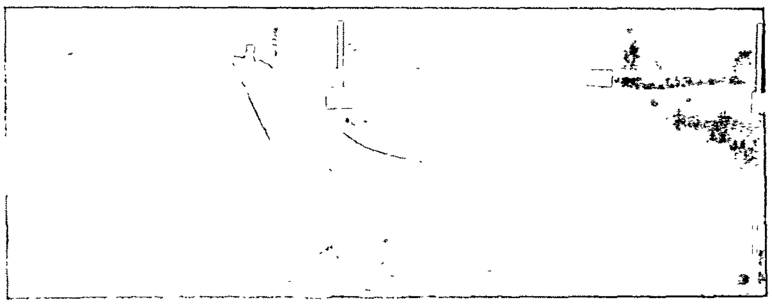
[redacted]



Near contact



72 feet

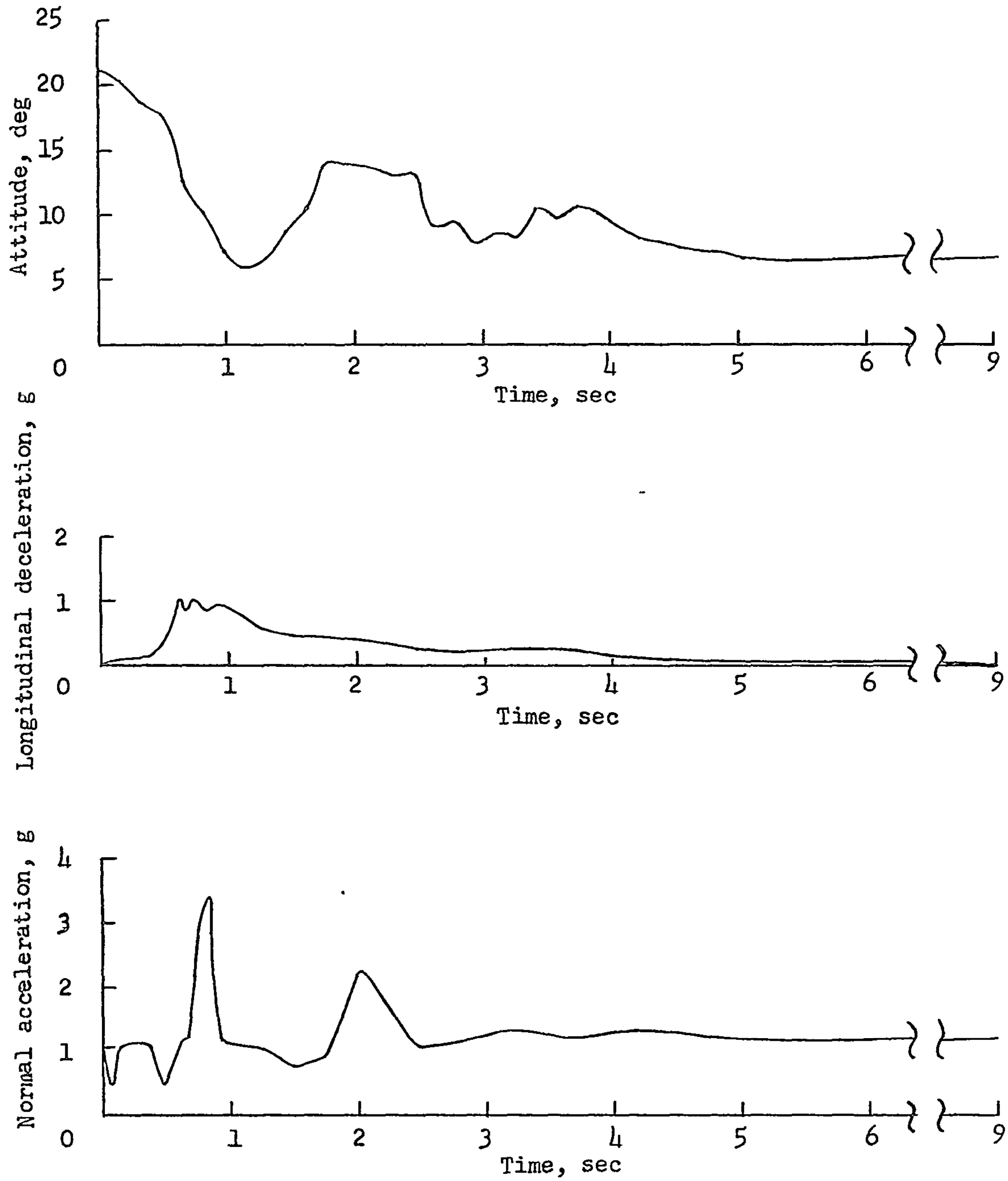


156 feet

(c) Scale-strength landing gear installed. L-93547

Figure 6.- Concluded.

 [redacted]

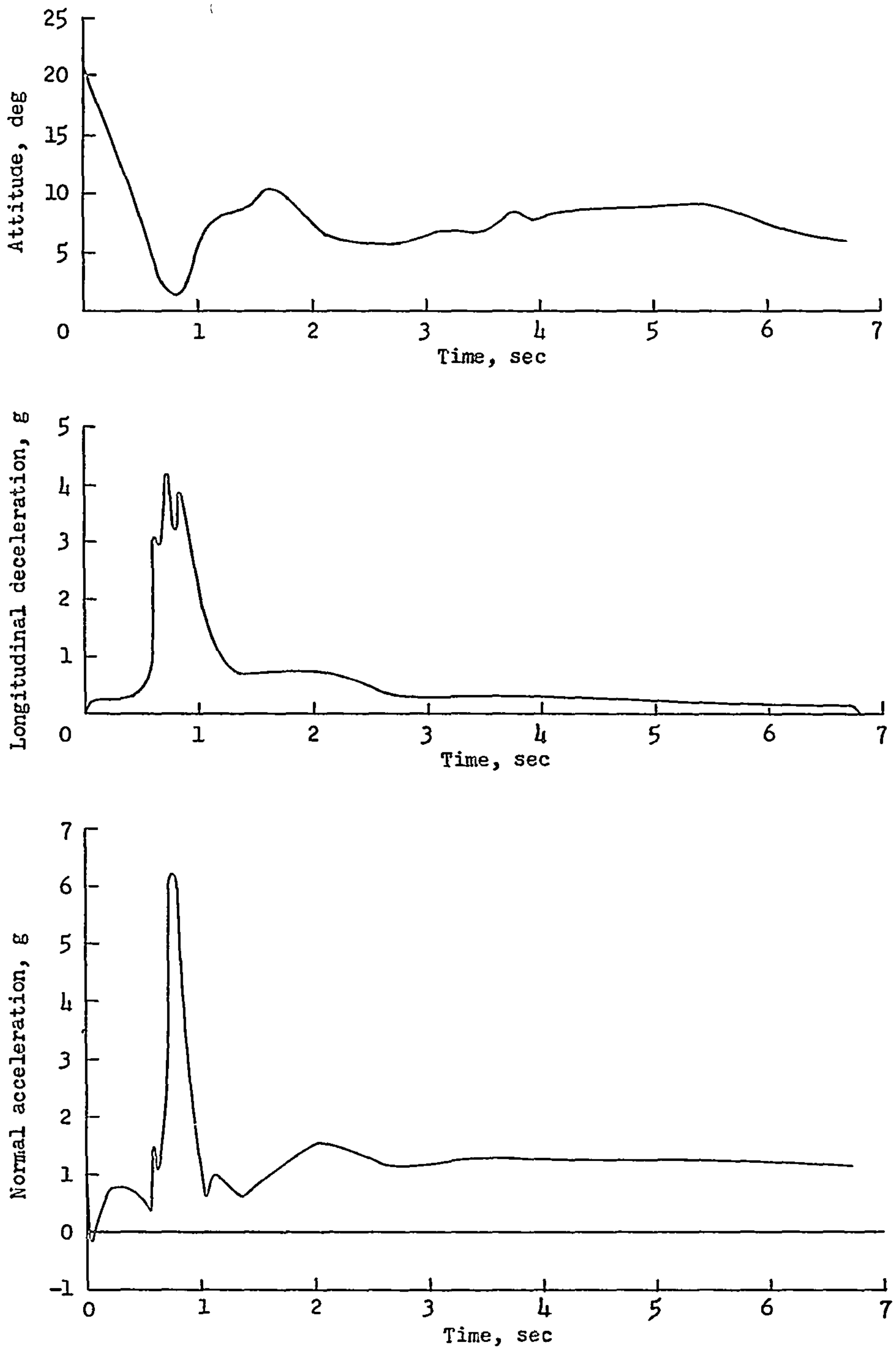



(a) No damage simulated.

Figure 7.- Attitude, longitudinal deceleration, and normal acceleration curves at the 22° landing attitude; landing speed, 90 knots.

[redacted]

[redacted]




(b) Aluminum-covered frame installed.

Figure 7.- Continued.

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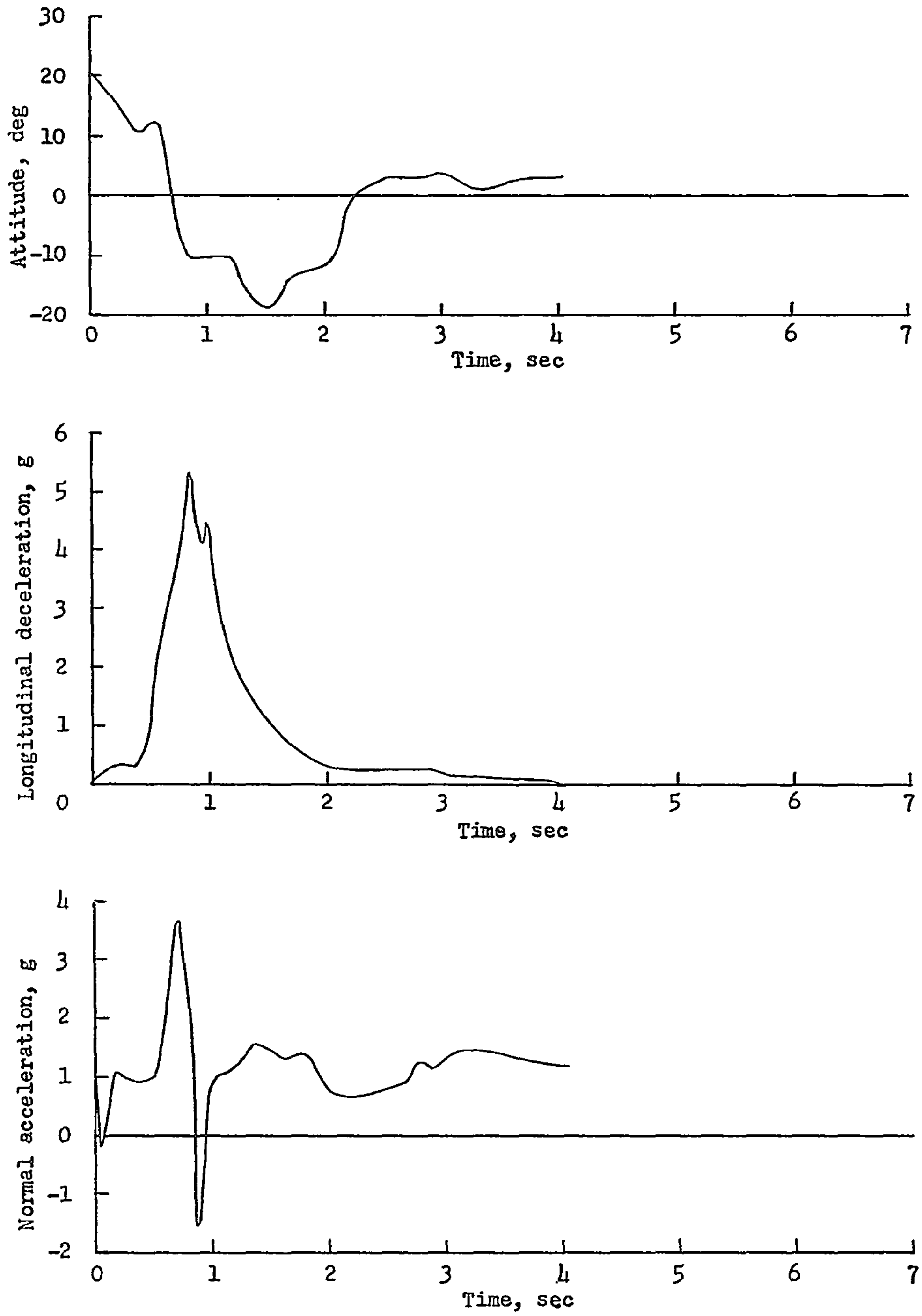


(c) Scale-strength landing gear installed.

Figure 7.- Concluded.

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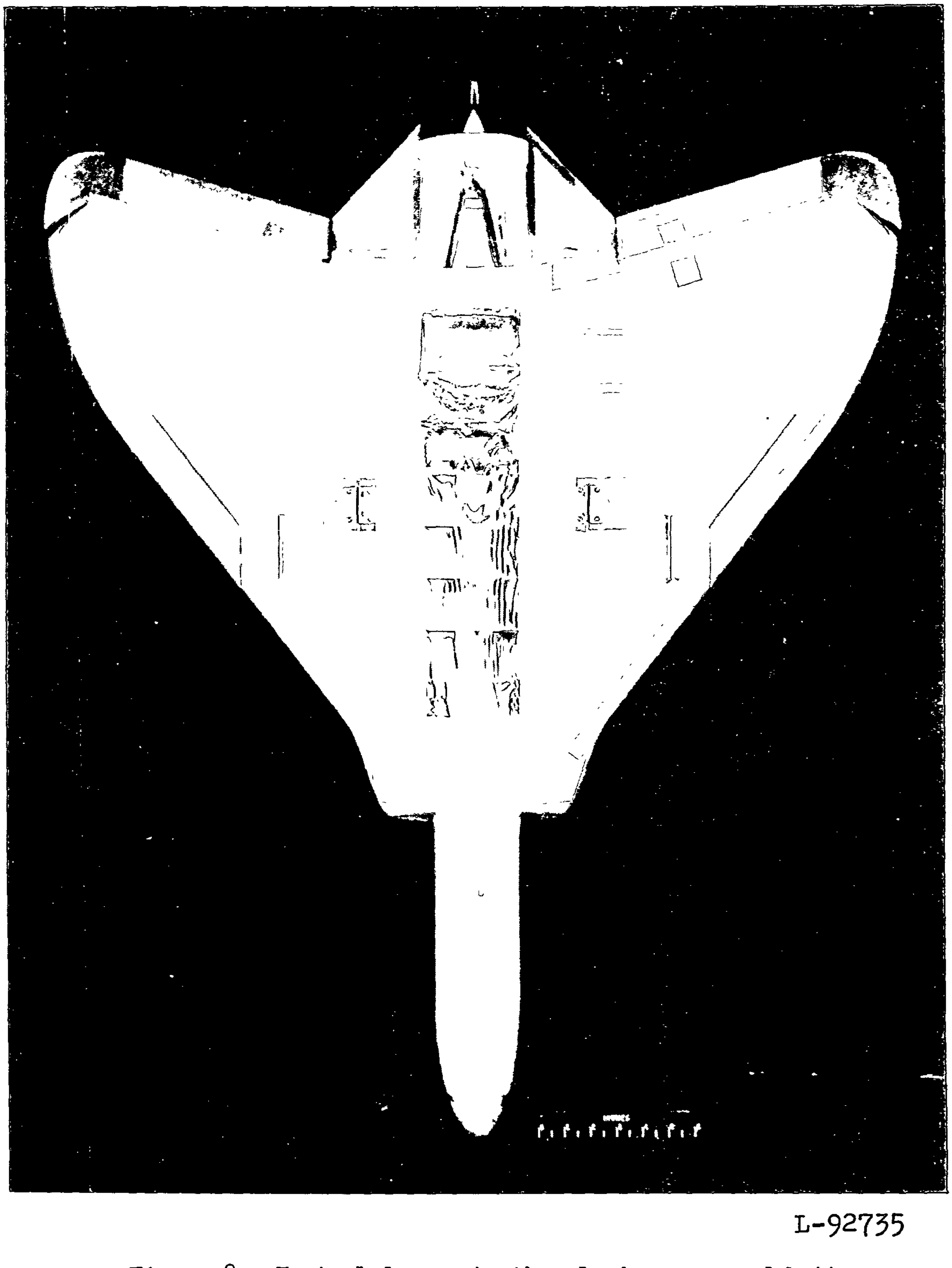

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Figure 8.- Typical damage to the aluminum-covered bottom.

[redacted]

[redacted]

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## ABSTRACT

Calm-water ditching tests were made at various landing attitudes, speeds, and configurations. It was concluded that the airplane should be ditched at the lowest speed and highest attitude consistent with adequate control (near $22^{\circ}$) with landing gear retracted. Under these conditions the airplane will probably nose in slightly, then make a fairly smooth run. Appreciable damage and short flotation time are likely. Moderate accelerations are to be expected in a landing run of about 170 feet.

[redacted]